A Guide to the Development of on-Site Sanitation, © WHO, 1992

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Acknowledgments

The World Health Organization is a specialized agency of the United Nations with primary responsibility for international health matters and public health, Through this organization, which was created in 1948, the health professions of some 170 countries exchange their knowledge and experience with the aim of making possible the attainment by all citizens of the world by the year 2000 of a level of health that will permit them to lead a socially and economically productive life.

By means of direct technical cooperation with its Member States, and by stimulating such cooperation among them, WHO promotes the development of comprehensive health services, the prevention and control of diseases' the improvement of environmental conditions, the development of human resources for health, the coordination and development of biomedical and health services research, and the planning and implementation of health programmes.

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Progress towards better health throughout the world also demands international cooperation in such matters as establishing international standards for biological substances, pesticides and pharmaceuticals: formulating environmental health criteria; recommending international nonproprietary names for drugs; administering the International Health Regulations; revising the International Statistical Classification of Diseases and Related Health Problems; and collecting and disseminating health statistical information.

Reflecting the concerns and priorities of the Organization and its Member States, WHO publications provide authoritative information and guidance aimed at promoting and protecting health and preventing and controlling disease.

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Safe disposal of excrete is of fundamental importance, not only for the health of the community, but also because of the social and environmental benefits it brings. However, for many low-income communities, particularly in developing countries, installation of; i a sewerage system, with its high cost and need for a piped water supply, is not a feasible option. For such communities, on-site disposal - dealing with excrete where they are deposited - offers a hygienic and affordable solution.

This book provides in-depth technical information about the design, construction, operation and maintenance of the major types of on-site sanitation facility, from simple pit latrines to aqua privies and septic tanks, with numerous practical design examples. Recognizing that the introduction of on-site sanitation system) involves considerably more than the application of simple, engineering techniques, the authors describe in detail the planning and development processes, and the financial and institutional factors that will need to be taken into account. Particular emphasis is given to the need to involve the community at all stages from planning to evaluation, to adapt projects and programmes to the local situation, and to provide continuing support to the community after the system is installed.

Based on the authors' experiences in a number of developing countries, this book will be of interest to a wide range of readers, from engineers and sanitarians to health personnel, administrators, planners and others concerned with improving sanitation in poor communities.

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Preface

For nearly thirty years, the names Wagner and Lanoix have recurred time and time again in connection with water supply and excrete disposal for rural areas and small communities. Their two volumes published by the World Health Organization in the late 1950s (Wagner & Lanoix, 1958, 1959) have stood the test of time.

Since their publication, there has been a massive increase in interest in water supply and sanitation, partly associated with the International Drinking Water Supply and Sanitation Decade (1981-1990). Many countries prepared programmes for the Decade that included optimistic forecasts for the provision of sanitation, but achieving the objectives has proved to be difficult. The majority of people living in rural areas and on the urban fringes in developing countries still lack satisfactory sanitation.

Some excellent publications, dealing with various aspects of appropriate technology for sanitation, have been produced by the World Bank and others. Much of the technology is a refinement of already known and practiced methods, based on experience in a number of developing countries in Africa, Asia and Latin America. However, emphasis has been given to socioeconomic aspects of planning and implementing sanitation Improvements.

This publication has therefore been prepared in response to these developments, as an update of Wagner & Lanoix's work, on which it draws heavily. The change of title is intended to focus attention on sanitation facilities on the householder's property, which are appropriate for some urban areas, as well as rural areas and small communities.

The book has three parts. Part I deals with the background to sanitation - health, sociological, financial and institutional issues, and the technologies available for excrete disposal. Part II provides in depth technical information about the design, construction, operation and maintenance of the major types of on-site sanitation facility, while Part III describes the planning and development processes involved in projects and programmes. Annexes on reuse of excrete and sullage disposal are also included; although connected with on-site sanitation, these are primarily off-site activities.

The book has been compiled with the needs of many different readers in mind. The authors hope that it will prove useful for engineers, medical officers and sanitarians in the field, and also for administrators, health personnel, planners, architects, and many others who are concerned with improving sanitation in rural areas and underprivileged urban communities in developing countries.

The views expressed in this publication reflect the authors' field experience in many developing countries, supplemented by discussion with other workers and study of recent publications. The book in its final form has greatly benefited from the comments of the reviewers listed in Annex 3, whose experience and knowledge are internationally recognized. Special thanks are due to Mr J. N. Lanoix for his thorough review and comments, and to M. Bell, A. Coad, A. Cotton, M. Ince and M. Smith of WEDC for their invaluable input.

Although every effort has been made to represent a world view, the authors have been constantly aware of great variations in practices in different continents, countries and districts. Sometimes what is quite satisfactory for one community is rejected by other people living nearby. When applying the information given in this book it is wise to follow the advice of Dr E. F. Schumacher: "Find out what the people are doing, and help them to do it better."

Part I - Foundations of sanitary practice

Chapter 1 - The need for on-site sanitation

Introduction

"Sanitation" refers to all conditions that affect health, especially with regard to dirt and infection and specifically to the drainage and disposal of sewage and refuse from houses (The Concise Oxford Dictionary). At its first meeting in 1950, the WHO Expert Committee on Environmental Sanitation defined environmental sanitation as including the control of community water supplies, excrete and wastewater disposal, refuse disposal, vectors of disease, housing conditions, food supplies and handling, atmospheric conditions, and the safety of the working environment. Environmental problems have since grown in complexity, especially with the advent of radiation and chemical hazards. Meanwhile, the world's needs for basic sanitation services (i.e., drinking-water supply, excrete and wastewater disposal) have greatly increased as a result of rapid population growth and higher expectations. This led to the designation by the United Nations of the International Drinking Water Supply and Sanitation Decade (1981-1990).

There has been considerable awareness of community water supply needs, but the problems of excrete and wastewater disposal have received less attention. In order to focus attention on these problems, "sanitation" became used and understood by people worldwide to refer only to excrete and wastewater disposal. A WHO Study Group in 1986 formally adopted this meaning by defining sanitation as "the means of collecting and disposing of excrete and community liquid wastes in a hygienic way so as not to endanger the health of individuals and the community as a whole" (WHO, 1987a). Hygienic disposal that does not endanger health should be the underlying objective of all sanitation programmes.

The cost of a sewerage system (which is usually more than four times that of on-site alternatives) and its requirement of a piped water supply preclude its adoption in the many communities in developing countries that lack adequate sanitation. On-site disposal, dealing with excrete where it is deposited, can provide a hygienic and satisfactory solution for such communities.

Safe disposal of excrete is of paramount importance for health and welfare and also for the social and environmental effects it may have in the communities involved. Its provision was listed by the WHO Expert Committee on Environmental Sanitation in 1954 among the first basic steps that should be taken towards ensuring a safe environment (WHO, 1954). More recently a WHO Expert Committee on the

Prevention and Control of Parasitic Infections (WHO, 1987b) stressed that "the provision of sanitary facilities for excrete disposal and their proper use are necessary components of any programme aimed at controlling intestinal parasites. In many areas, sanitation is the most urgent health need and those concerned with the control of intestinal parasitic infections are urged to promote intersectoral collaboration between health care authorities and those responsible for the provision of sanitation facilities and water supply at the community level."

Historical evidence

There is historical evidence from the industrialized world of the need for sanitation as a high priority for health protection. For example, in England in the nineteenth century, exposure to water-related infections was reduced when government-sponsored environmental measures were taken following enactment of public health legislation.

The present situation

Improved sanitation and domestic water supply warrant high priority for investment in developing countries where they are at the forefront of health improvements in both rural and urban communities. The importance attached to sanitation is part of a movement towards satisfaction of basic human needs - health care, housing, clean water, appropriate sanitation and adequate food. This movement has been instrumental in promoting a shift from curative to preventive medicine and in the designation of the 1980s as the International Drinking Water Supply and Sanitation Decade.

Decade approaches

The decision to designate the Decade was taken at the United Nations Water Conference held in Mar del Plata in 1977. The Conference also agreed a plan of action, recommending that national programmes should give priority to:

- the rural and urban underserved populations;
- application of self-reliant and self-sustaining programmes;
- use of socially relevant systems;
- association of the community in all stages of development;
- complementarily of sanitation with water supply; and
- the association of water supply and sanitation with health and other sector programmes.

The shortfall in sanitation

The percentage of the total population in the developing countries of the WHO Regions who do not have adequate sanitation is shown in

Table 1.1. Percentage of the population without adequate sanitation [a]

WHO	1970		1975		1980		1988	
region	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Africa	53	77	25	72	46	80	46	79
Americas	24	76	20	75	44	80	10	69
Eastern Mediterranean	38	88	37	86	43	93	6	80
South-East Asia	67	96	69	96	70	94	59	89
Western Pacific	19	81	19	57	7	37	11	31
Global total	46	91	50	89	50	87	33	81

[a] From WHO,1990

Table 1.1, which is derived from statistics available to the Organization (WHO, 1990).

Notwithstanding some inaccuracies in reporting, there is abundant evidence that the scale of the problem is greatest in countries with a low gross national product (GNP) and especially in rural communities. There are also marked disparities in environmental conditions and in standards of health within the developing countries and particularly in the major cities.

Problems of urban growth

Rates of urban growth of greater than 5% per year have produced concentrations of poor people in city-centre slums and in squatter areas on the periphery of towns and cities. Health risks are high in these areas. High-density living promotes the spread of airborne respiratory infections and hygiene-related diseases such as diarrhoea. Malnutrition is common and hence people are more susceptible to water-related infections. Such infections can spread rapidly since water sources are liable to faecal pollution. A major challenge for those concerned with environmental health is the design and introduction of excrete disposal systems appropriate to these high-density, low-income communities.

Rural problems

There is an equal need for the hygienic disposal of excrete and the promotion of health in rural areas. Rural communities may have evolved what they perceive to be satisfactory disposal systems, but the introduction of improved sanitation facilities can form a useful part of broader rural development programmes. The level of sanitation provision should be linked to that of other facilities in the community, and to the community's ability to support (financially and culturally) and maintain such provisions.

Constraints

The many constraints on improving health through better sanitation centre on the political, economic, social and cultural contexts of health and disease. Worldwide surveys conducted by WHO identified the following as the most serious constraints:

- funding limitations;
- insufficiency of trained personnel;
- operation and maintenance;
- logistics;
- inadequate cost-recovery framework;
- insufficient health education efforts;
- inappropriate institutional framework;
- intermittent water service;
- non-involvement of communities.

Priorities

There are four main targets for sanitation programmes: rural development, urban upgrading, periurban shanty and squatter upgrading, and new urban development. Programmes for these areas may be similar in content or approach. For example, both rural and shanty town development may have a high level of community contribution in labour, yet they may be very different in the input of health education, introduction or enhancing awareness of new technologies, development of managerial structure, and provision of finance.

Questions have arisen concerning the kinds of technology that are most appropriate to the communities to be served and how this technology can best be introduced. The need for technical specialists to be aware of the social and cultural context of engineering interventions has been emphasized together with the need for popular participation in project design and implementation. Concepts such as grass-roots development, based on an approach that builds from below, have offered a challenge to the top-down approach based on decisions made at high managerial levels. The former is critical in sanitation programmes, since the effectiveness of these programmes depends not merely on community support but, more particularly, on the consent and commitment of households and individual users. Further, in sanitation programmes, technical and social decisions are closely interrelated.

Chapter 2 - Sanitation and disease transmission

Diseases associated with excrete and wastewater

Sources of disease

The inadequate and insanitary disposal of infected human faeces leads to the contamination of the ground and of sources of water. Often it provides the sites and the opportunity for certain species of flies and mosquitos to lay their eggs, to breed, or to feed on the exposed material and to carry infection. It also attracts domestic animals, rodents and other vermin which spread the faeces and with them the potential for disease. In addition it sometimes creates intolerable nuisances of both odour and sight.

There are a number of diseases related to excrete and wastewater which commonly affect people in the developing countries and which can be subdivided into communicable and noncommunicable diseases.

Communicable diseases

The major communicable diseases whose incidence can be reduced by the introduction of safe excrete disposal are intestinal infections and helminth infestations, including cholera, typhoid and paratyphoid fevers, dysentery and diarrhoea, hookworm, schistosomiasis and filariasis.

Table 2.1 lists some of the pathogenic organisms frequently found in faeces, urine and sullage (greywater).

Country	Infant mortality rate per 1000 live births		Child mortality per 1000 (1–5 years)	Life expectancy at birth (years)		Population below poverty line (%)	
	1983	1985		1983	1985	Urban	Rural
Bangladesh	130	121	205	48	54	86	86
Ecuador	70	45	95	63	64	30	65
Finland	6	6	8	73	75	—	—
Haiti	130	125	190	53	54	55	78
India	110	114	165	53	54	40	51
Malaysia	30	17	41	67	70	13	38
Nepal	140	140	215	46	52	55	61
Papua New Guinea	75	72	105	53	50	10	75
Paraguay	45	30	65	65	65	19	50
Philippines	50	57	85	65	63	32	41
Sierra Leone	180	225	310	34	47	—	65
Thailand	48	12	60	63	63	15	34
Trinidad and Tobago	24	19	28	70	67	—	39
United Kingdom	10	12	12	74	73	—	—

[a] From UNICEF (1986); WHO (1987c).

High-risk groups

Those most at risk of these diseases are children under five years of age, as their immune systems are not fully developed and may be further impaired by malnutrition. The diarrhoeal diseases are by far the major underlying cause of mortality in this age group, accounting for some 4 million deaths each year.

In 1973, children in Brazil under one year of age totalled less than one-fifth of the population but suffered almost four-fifths of all deaths, while in the United States of America this age group represented 8.8% of the population and suffered only 4.3% of deaths (Berg, 1973).

Table 2.1. Occurrence of some pathogens In urine, [a] faecea and sullage [b]

Pathogen	Common name for infection caused	Present in:		
		urine	faeces	sullage
Bacteria:				
Escherichia coli	diarrhoea	*	*	*
Leptospira interrogans	leptospirosis	*		
Salmonella typhi	typhoid	*	*	*
Shigella spp	shigellosis		*	
Vibrio cholerae	cholera		*	
Viruses:				
Poliovirus	poliomyelitis		*	*
Rotaviruses	enteritis		*	
Protozoa - amoeba or cysts:				
Entamoeba histolytica	amoebiasis		*	*
Giardia intestinalis	giardiasis		*	*
Helminths - parasite eggs:				
Ascaris lumbricoides	roundworm		*	*
Fasciola hepatica	liver fluke		*	
Ancylostoma duodenale	hookworm		*	*
Necator americanus	hookworm		*	*
Schistosoma spp	schistosomiasis	*	*	*
Taenia spp	tapeworm		*	*
Trichuris trichiura	whipworm		*	*

[a] Urine is usually sterile; the presence of pathogens indicates either faecal pollution or host infection, principally with Salmonella typhi, Schistosoma haematobium or Leptospira.

[b] From Cheesebrough (1984), Sridhar et al. (1981) and Feachem et al. (1983).

There is no doubt that improving the sanitation within a community should lead to an improvement in health, but it is difficult to ascertain whether the impact would be direct or indirect. Often, provision of better sanitation is part of broader development activities within the community and, even if dissociated from improvement of the water supply, there are usually other factors that influence health which are introduced with sanitation changes, e.g., health and hygiene education (Blum & Feachem, 1983). The effect of these factors, such as increased handwashing or changes in attitudes to children's excrete, may be difficult to monitor and/or evaluate.

Table 2.2 gives details for different countries of infant and child deaths (including deaths from diarrhoea), life expectancy at birth, and the levels of poverty in both urban and rural areas. In general, these data reflect an interactive relationship between poverty/malnutrition and children's health. In turn, this relationship may be related to the level of sanitation in the children's environment. For instance, the incidence of diarrhoeal disease in children is affected by poor personal hygiene and environmental sanitation, and also by reduced resistance to disease in malnutrition. Diarrhoea leads to loss of weight, which is normally transitory in the well nourished but more persistent in the malnourished. Repeated infections can lead to increased malnutrition which in turn increases susceptibility to further infection; this may be referred to as the diarrhoea malnutrition cycle.

Table 2.2. Health indicators [a]

Country	Infant mortality rate per 1000 live births		Child mortality per 1000 (1–5 years)	Life expectancy at birth (years)		Population below poverty line (%)	
	1983	1985		1983	1985	Urban	Rural
Bangladesh	130	121	205	48	54	86	86
Ecuador	70	45	95	63	64	30	65
Finland	6	6	8	73	75	—	—
Haiti	130	125	190	53	54	55	78
India	110	114	165	53	54	40	51
Malaysia	30	17	41	67	70	13	38
Nepal	140	140	215	46	52	55	61
Papua New Guinea	75	72	105	53	50	10	75
Paraguay	45	30	65	65	65	19	50
Philippines	50	57	85	65	63	32	41
Sierra Leone	180	225	310	34	47	—	65
Thailand	48	12	60	63	63	15	34
Trinidad and Tobago	24	19	28	70	67	—	39
United Kingdom	10	12	12	74	73	—	—

[a] From UNICEF (1986); WHO (1987c).

Noncommunicable diseases

In addition to pathogen content, the chemical composition of wastewater has to be considered because of its effects on crop growth and/or consumers. The number of components to be monitored (e.g., heavy metals, organic compounds, detergents, etc.) is greater in industrialized urban areas than in rural areas. Nitrate content is important, however, in all areas because of the possible effects of its accumulation, in both surface and groundwater, on human health (methaemoglobinaemia in infants), and on the ecological balance in waters receiving runoff or effluent high in nitrates. Although the major human activity resulting in the increase of nitrate levels is the use of chemical fertilizers, poor sanitation or misuse of wastewater can contribute to or, in exceptional cases, be the major determinant of nitrate levels, particularly in groundwater.

How disease is carried from excrete

Transmission of diseases

Humans themselves are the main reservoir of most diseases that affect them. Transmission of excrete-related diseases from one host to another (or the same host) normally follows one of the routes shown in Fig. 2.1. Poor domestic and personal hygiene, indicated by routes involving food and hands, often diminishes or even negates any positive impact of improved excrete disposal on community health. As shown in the figure, most routes for transmission of excrete-related diseases are the same as those for water-related diseases, being dependent on faecal - oral transmission (waterborne and water-washed) and skin penetration (water-based with an aquatic host; soil-based but not faecal oral; and insect vector with vector breeding on excrete or in dirty water). Table 2.3 gives examples of excrete-related diseases and data on the number of infections and deaths per year.

Fig. 2.1. Transmission routes for pathogens found In excrete

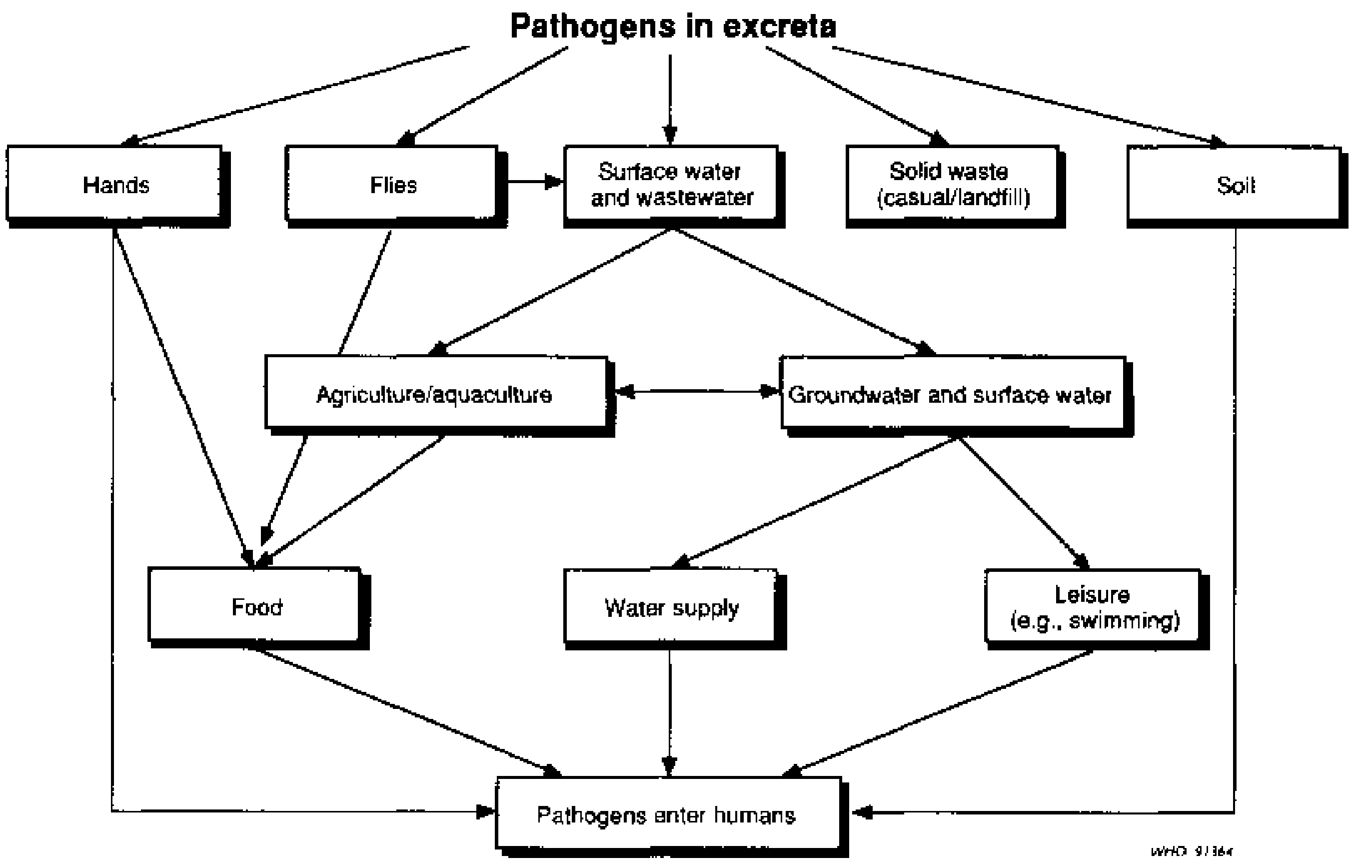


Table 2.3. Morbidity and mortality associated with various excretarelated disease [a]

Disease	Morbidity	Mortality (no. of deaths per year)	Population at risk
Waterborne and water-washed			
diarrhoea	1500 million or more	4 million in children	More than
	episodes in children	under 5 years	2000 million
	under 5 years		
poliomyelitis	204 000	25 000	
enteric fevers (typhoid, paratyphoid)	500000-1 million	25000	
roundworm	800-1000 million infections	20000	
Waler-based			
schistosomiasis	200 million	More than 200000	500-600 million
Soil-based			
hookworm	900 million infections	50000	

As Table 2.3 illustrates, diarrhoeal diseases and helminth infections account for the greatest number of cases per year although there is a considerable difference in the levels of debility they produce. Schistosomiasis has relatively high rates of infection and death. The socioeconomic impact of these diseases should not be ignored or underestimated. To illustrate this further, schistosomiasis will be considered in greater detail.

Schistosomiasis

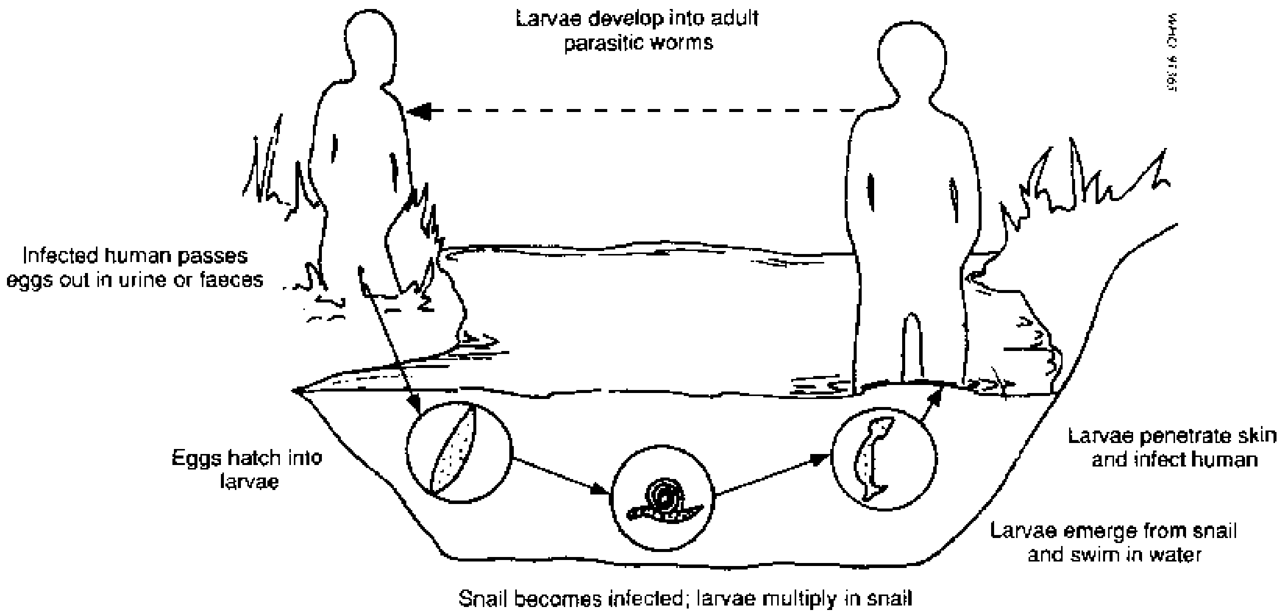
Schistosomiasis is acquired through repeated contact with surface water contaminated with human excrete (both urine and faeces) containing schistosomes (WHO, 1985). Contact can be via agriculture, aquaculture, leisure activities (particularly swimming), collection of water, washing and bathing. Of the parasitic diseases, schistosomiasis ranks second in terms of socioeconomic and public health importance in tropical and subtropical areas, immediately behind malaria.

In 1990, schistosomiasis was reported to be endemic in 76 developing countries. Over 200 million people in rural and agricultural areas were estimated to be infected, while 500 600 million more were at risk of becoming infected, because of poverty, ignorance, substandard hygiene, and poor housing with few, if any, sanitary facilities.

People with light infections as well as those with obvious symptoms suffer weakness and lethargy, which decrease their capacity for work and productivity.

As shown in Fig. 2.2, the parasite develops in snails, the intermediate hosts. The free-swimming stage of the parasite penetrates the skin of humans and, if infection is heavy, the disease develops. The incidence of diseases such as schistosomiasis should be much reduced by the provision of sanitation. However, for this disease, as for many others, additional measures including the provision of safe drinking water can also interrupt transmission by reducing contact with infested water. People living in endemic areas can benefit greatly from health education aimed at increasing their understanding of their rode in transmission, and the importance of the use of latrines. Since young children are often most heavily infected, early use of latrines, especially in schools, will promote healthy habits.

Fig. 2.2. The cycle of transmission of schistosomiasis



Reuse of excrete and wastewater in agriculture

Sanitation is not always the only factor to be considered when relating excrete disposal to disease transmission within and between communities. The reuse of excrete (untreated or treated to differing extents) as a fertilizer, and reuse of wastewater (including sullage water) for many purposes, but especially for irrigation, may also contribute to the incidence of excrete-related diseases. In many countries where the demand for water is greater than the supply, use of wastewater for irrigation of crops for consumption by animals or humans can have a major impact on community health. This is especially important in areas with poor soils and insufficient income for purchase of commercial fertilizers and conditioners, where the use of human as well as animal excrete to condition and fertilize soil is actively encouraged. With such practices the degree of the hazard is dependent on several parameters including:

- the level (or lack) of treatment prior to reuse;
- the nature of the crop;
- the method of irrigation;
- the extent of reuse;
- the incidence and type of disease in the area;
- air, soil and water conditions.

The groups most at risk of infection will also depend on these factors and on other agricultural practices. The diseases that may show the greatest increase in incidence where reuse is practiced are

helminth infestations, particularly hookworm, roundworm and whipworm; schistosomiasis may also increase markedly in some circumstances. Bacterial infections, such as cholera and diarrhoea, are affected to a much smaller degree, with the incidence of viral infections being least affected by these practices (Mare & Cairncross, 1989; WHO, 1 989).

Epidemiological characteristics of pathogens

Pathogen survival

The survival times and other epidemiological characteristics of organisms in different media are given in Table 2.4; it should be noted that these periods are approximate, being dependent on local factors such as the climate and the number (concentration) and species of organisms.

Pathogen infectivity and latency

In addition to knowing how long the infectious agent may survive, i.e., its persistence, knowledge of the infectivity and latency of the organism is of value. Some pathogens remain infective for only short periods after being excreted, yet the incidence of associated disease is high. This may be attributable to the low infectious dose of the organism, e.g., protozoa! cysts. The latency of an organism (i.e., the period between leaving a host and becoming infective) can vary from zero for some bacterial infections to weeks for some helminth eggs. For example, schistosome eggs have a latency of a few weeks during which time they develop in an intermediate host into the infective, free swimming cercariae (Fig. 2.2); however, both the eggs and the cercariae have a persistence of only a few hours if they do not enter a new host (intermediate or human). In contrast, Ascaris eggs can become infective within ten days of being excreted (latency) but may remain in the soil for at least a year and still be infective (persistence).

Table 2.4. The epidemiological characteristics of excreted pathogensa

Pathogen	Latency period	ID_{50}[b]	Survival times for pathogens in:		
			wastewater	soil	crops
Bacteria	0	$>10^4$	few days to 3 months		
Vibrio cholerae	0	10^8	~1 month	<3 weeks	<5 days
Faecal coliform	0	$\sim 10^9$	~3 months	<2 months	<1 month
Viruses	0	unknown	months	months	1–2 months
Enteroviruses[c]	0	100	~3 months	<3 months	<2 months
Protozoa (cysts)	0	10–100	few days to few weeks		
Entamoeba spp	0	10-100	25 days	<3 weeks	<10 days
Helminths[d]	variable	1–100	months	months	months
Ancylostoma spp	1 week	1	3 months	<3 months	<1 month
Ascaris spp	10 days	several	~1 year	many months	<3 months
Flukes[e]	6–8 weeks	several	life of host[f]	hours[f]	hours[f]

[a] Sources: Feachem et al. (1983); WHO (1987a).
[b] The ID_{50} is the number of organisms required to cause the development of clinical symptoms in 50% of individuals.
[c] Including coxsackieviruses, echoviruses and polioviruses.
[d] Eggs or larvae/cercariae.
[e] Excluding *Fasciola hepatica* but including *Schistosoma* spp.
[f] Outside the aquatic host, the pathogen survives for only a few hours. In the host, survival is for the life of the host.

Control of excrete-related diseases

If transmission is blocked at one or more points, excrete-related diseases can be controlled or possibly eradicated. Sanitation provides one such block. For example, water-seal slabs in latrines reduce the breeding sites for culicine mosquitos, vectors of filariasis; treatment of excrete prior to its disposal can kill the eggs and cysts of many human parasites (Ascaris, Entamoeba, and Schistosoma spp), thus preventing contamination of both ground and water.

Relationship of health to disposal method

The technical objective of sanitary excrete disposal is to isolate faeces so that the infectious agents in them cannot reach a new host. The method chosen for any particular area or region will depend on many factors including the local geology and hydrogeology, the culture and preferences of the communities, the locally available raw materials and the cost (both short-term and long-term).

The types of disease that are endemic in an area should also be considered. The survival of endemic pathogens (eggs, cysts, infectious agents) and the destination or possible reuse of different products of disposal/treatment can have a great effect on incidence of disease in that area and, possibly, adjacent areas.

The possible sites for both negative and positive impacts on health, taking all the above parameters into consideration, should be considered during the planning stages of development projects to improve sanitation. This should ensure that the projects achieve the greatest possible effect on the incidence of diseases related to excrete and wastewater in the community.

Chapter 3 - Social and cultural considerations

The introduction of on-site sanitation systems is much more than the application of simple engineering techniques - it is an intervention that entails considerable social change. If sanitation improvements in rural and urban areas are to be widely accepted, the relevant social and cultural factors have to be taken into consideration during planning and implementation. It is therefore necessary to understand how a society functions, including the communities and households within it, and what factors promote change.

Social structure

Consideration should be given to the institutions of a political, economic and social nature that are operating at the national and/or local level, such as government, the civil service, religious institutions, schools and colleges, and the family, and to the forms of leadership and authority that are generally accepted by the majority of the people. It is also important to consider the various roles and patterns of behaviour of individuals and social groups, and to determine who is traditionally responsible for such areas as water supplies, environmental hygiene, family health and children's defecation habits, etc.

Cultural beliefs and practices

Group and community identity, gender roles, the relative importance attached to different forms of authority and the ways in which it is exercised are all influenced by culture, i.e., all that is passed down by human society including language, laws, customs, beliefs and moral standards. Culture shapes human behaviour in many different ways including the status attached to different roles and what is deemed to be acceptable personal and social behaviour. In many cultures, for example, the elderly command traditional authority and influence within the family and community.

As regards sanitation behaviour, defecation is often a private matter which people are unwilling to discuss openly, while the burying of faeces is widely practiced to ward off evil spirits. Contact with faecal matter is unacceptable to certain individuals in societies where it is the responsibility of low-income or low-caste groups, while taboos may dictate that separate facilities should be provided for particular social groups.

A particular cultural practice to be considered, which has direct technical consequences, is the method of anal cleansing used by the community. Whether water, stones, corncobs or thick pieces of paper are used will affect the design of the sanitation system.

Culture also influences how people interpret and evaluate the environment in which they live. Investments in sanitation seek to improve health by providing a clean physical environment for households. There is a logical series of technical questions that need to be asked in order that acceptable technical solutions can be found. It may be confusing, therefore, when sanitation behaviour is found to vary widely between communities within the same physical environment. Predetermined rules cannot be applied. However, the sanitation behaviour of individuals usually has a rational basis, and people are often aware of the environmental causes of ill-health. Many societies have a detailed knowledge of the physical environment as a provider of resources for curative and preventive medicine and as a cause of illness. More than this, they have an understanding of the environment, not only in its physical sense, but also in relation to social and spiritual factors. This holistic view of the environment permeates many of the cultural beliefs and customs that impinge on both water use patterns and sanitation behaviour. Some illustrations of these beliefs are given below.

Concepts of hygiene

Although communities may lack knowledge of modern medical explanations of disease, they often have concepts of what is pure and polluting. Of the water resources available to particular households for domestic purposes, running water may be most acceptable for drinking because it is exposed to the sunlight; it is considered to be "alive" and therefore "pure", while water in shallow wells, which does not have these attributes, is deemed suitable only for washing and cooking. Communities have been observed to use the environmental resources available to them, such as bamboo, to bring fast-flowing river water to their villages in preference to more convenient well water that is unacceptable in taste, colour and smell.

Concepts of clean and dirty, pure and polluting, are well developed in the major world religions, and have a ritual and spiritual significance as well as referring to a physical state. When people are told that new sanitation facilities will make their environment "cleaner", it is their own interpretation of this concept that will be used. "Clean" may have quite different meanings to project promoters and recipients. Thus "it is essential to look into traditional categories of cleanliness and dirtiness, purity and pollution before embarking on a campaign to motivate people to accept a project in improved... sanitation or to change their behaviour to comply with new standards of "cleanliness" (Simpson-Hebert, 1984).

Beliefs about sanitation and disease

Evidence of the value attached by communities to cleanliness and, by implication, environmental sanitation is found in studies of diarrhoea. People's perceptions of its causes may be divided into three categories, physical, social and spiritual. In many cases, physical causes are identified and, although the germ theory is not explicitly stated, the faecal oral transmission routes of diarrhoea appear to be understood. Households may associate diarrhoea with a polluted environment including uncovered food, dirty water and flies. Graphic descriptions of pollution have been quoted (de Zoysa et al., 1984):

- "We have to drink the dam water where animals and children bathe and the dirty water makes us ill."

- "Flies sit on dirt which they eat then they come on to uncovered foods and spit on to foods which we eat."

As on-site sanitation involves improving the physical environment, it may therefore be readily accepted as one means by which to reduce the incidence of disease.

Equally, social and spiritual causes are perceived to be important, and include, for example, female social indiscretions and witchcraft. But these three apparently unrelated causes of diarrhoea should not be interpreted as mutually exclusive or divergent approaches to disease. They are often closely interrelated in practice, within a holistic interpretation of the environment.

Efforts should be made to determine how a community's beliefs, knowledge, and control over the environment can be harnessed in a positive way. Careful judgment is required to distinguish between those beliefs and ritual behaviour that are conducive to good sanitation practice and those that need to be changed.

Forces for change

All societies undergo adjustments in their social structure and culture over time. This may result from contact between societies or from alterations in the physical environment such as prolonged drought. Further, changes in development practice and in international aid influence national goals and priorities with respect to different sectors and regions. How change is brought about and what it is that changes are important issues that need to be addressed.

The profound impact of forces for change on diverse societies finds expression in patterns of apparently increasing uniformity between countries and cultures. In demographic terms, these include rapid rates of national population growth, and internal migration of people from rural to urban areas coupled with urban expansion.

Responses to change

The responses of individuals and groups to urban life, to factory employment or to new technology are a product of the values, experiences and behaviour patterns that they have assimilated over time as members of particular communities and societies. Some groups and individuals are more open to change and more able to adapt to it than others. Decisions are taken to accept or resist an innovation on the basis of characteristics peculiar to the individual, household or group within the context of the local physical, social, economic, cultural and demographic environment.

Access to education may increase awareness of the health benefits of improved sanitation technology, while income will influence the ability of a household to acquire particular facilities. Personal experience and demonstration of alternative technologies may help to convince people that the benefits of the investment will outweigh any costs incurred. Community organizations and influential leaders can assist in marketing the concept by emphasizing factors valued locally. These may include the status attached to possessing a facility, or its functional value in terms of comfort. Equally, factors such as rapid increase in population which limits privacy may heighten the perceived need for innovations in sanitation.

People resist change for many reasons. There may be resentment towards outside "experts" who know little of local customs and who are perceived to benefit more from the innovation than local people. Leadership may not be united within a community. For example, those with traditional authority who fear a loss of power and status may oppose innovation strongly supported by political or educated elites. New technologies may be aesthetically unacceptable or conflict with established patterns of personal and social behaviour. Furthermore, households vary widely in the resources of money, labour and time available to them and have their own priorities. For those with limited resources, the costs in the short term of an apparently "low-cost" system may be too great when set against their need for food, shelter and clothing. In addition, in terms of capital investment latrines may be very costly for households if they take a long time to clean, are difficult to use or involve radical changes in social habits (Pacey, 1980). There may also be seasonal variations in the availability of money and labour. Thus the timing of the promotional aspects of a project in relation to, for example, agricultural seasons may be important in determining the local response.

The demographic composition, economic characteristics and attitudes to sanitation of individual households change over time. Experience shows that once people start to improve their houses their interest in latrines is likely to be aroused. Thus some households may be encouraged to install a latrine as one aspect of the modernization process. Projects should be flexible enough to allow households to invest in on-site sanitation not only when they feel motivated but also when they have the resources to do so. Indeed it may be most appropriate to introduce a range of on-site technologies within a particular community from which households can make a choice according to their own changing needs and priorities.

Conclusion

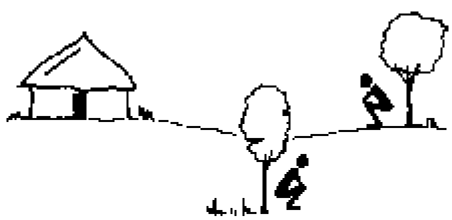
To identify a demand for improved sanitation is more positive than to initiate a supply of technology that is deemed to be good for communities. The former depends upon cooperation between providers and beneficiaries which comes through dialogue and the exchange of information. Individual users are the ultimate decision-makers in the acceptance or rejection of new technology. It is they who determine the success of a project, since the value of the investment depends not only upon community support but, more particularly, on the consent of households and individual users. They need to be convinced that the benefits of improved sanitation, and the new technology with which it is associated, outweigh the costs. Equally, it is for providers to appreciate the social context and the constraints within which individual decisions are made. They must learn from communities about why improved sanitation may elicit negative responses and also the positive features of community values, beliefs and practices which can be harnessed to promote change.

Chapter 4 - Technical options

In this chapter various sanitation systems are introduced with a brief indication of their suitability for particular situations, the constraints on their use, and their disadvantages. The whole range of options is covered, including off-site systems and some that are not recommended because of the associated health risk and other disadvantages. Each community must choose the most feasible and convenient option to provide necessary health protection. Selecting the most appropriate option requires a thorough analysis of all factors including cost, cultural acceptability, simplicity of design and construction, operation and maintenance, and local availability of materials and skills. Further details of the design, construction, operation and maintenance of these systems are given in Part II.

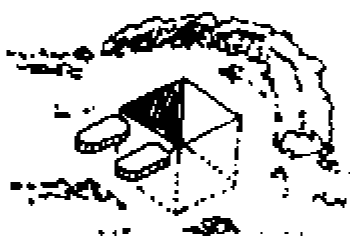
Open defecation

Where there are no latrines people resort to defecation in the open. This may be indiscriminate or in special places for defecation generally accepted by the community, such as defecation fields, rubbish and manure heaps, or under trees. Open defecation encourages flies, which spread faeces-related diseases. In moist ground the larvae of intestinal worms develop, and faeces and larvae may be carried by people and animals. Surface water run-off from places where people have defecated results in water pollution. In view of the health hazards created and the degradation of the environment, open defecation should not be tolerated in villages and other built-up areas. There are better options available that confine excrete in such a way that the cycle of reinfection from excrete-related diseases is broken.



Shallow pit

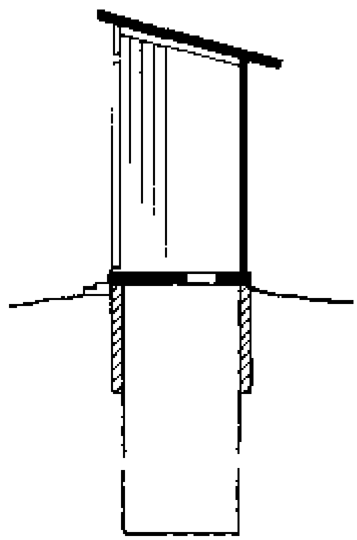
People working on farms may dig a small hole each time they defecate and then cover the faeces with soil. This is sometimes known as the "cat" method. Pits about 300 mm deep may be used for several weeks. Excavated soil is heaped beside the pit and some is put over the faeces after each use. Decomposition in shallow pits is rapid because of the large bacterial population in the topsoil, but flies breed in large numbers and hookworm larvae spread around the holes. Hookworm larvae can migrate upwards from excrete buried less than I m deep, to penetrate the soles of the feet of subsequent users.



Advantages	Disadvantages
No cost	Considerable fly nuisance
Benefit to farmers as fertilizer	Spread of hookworm larvae

Simple pit latrine

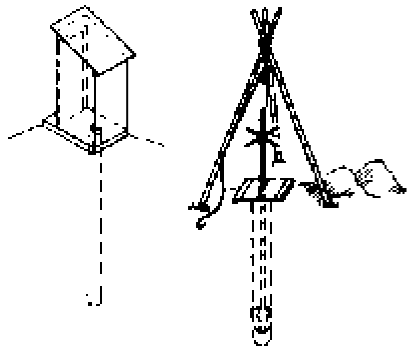
This consists of a slab over a pit which may be 2 m or more in depth. The slab should be firmly supported on all sides and raised above the surrounding ground so that surface water cannot enter the pit. If the sides of the pit are liable to collapse they should be lined. A squat hole in the slab or a seat is provided so that the excrete fall directly into the pit.



Advantages	Disadvantages
Low cost	Considerable fly nuisance (and mosquito nuisance if the pit is wet) unless there is a tight-fitting cover over the squat hole when the latrine is not in use
Can be built by householder	Smell
Needs no water for operation	
Easily understood	

Borehole latrine

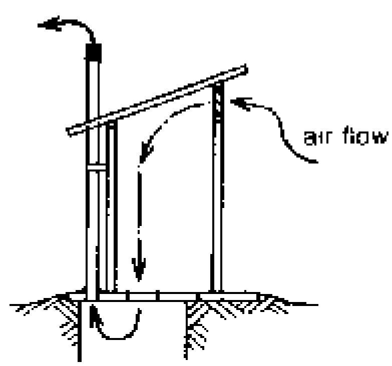
A borehole excavated by hand with an auger or by machine can be used as a latrine. The diameter is often about 400 mm and the depth 6 8 m.



Advantages	Disadvantages
Can be excavated quickly if boring equipment is available	Sides liable to be fouled, with consequent fly nuisance
Suitable for short-term use, as in disaster situations	Short life owing to small cross sectional area
	Greater risk of groundwater pollution owing to depth of hole

Ventilated pit latrine

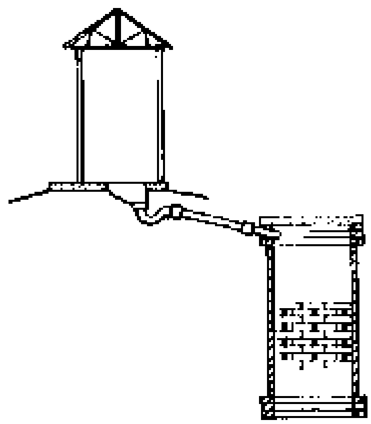
Fly and odour nuisance may be substantially reduced if the pit is ventilated by a pipe extending above the latrine roof, with fly-proof netting across the top. The inside of the superstructure is kept dark. Such latrines are known as ventilated improved pit (VIP) latrines.



Advantages	Disadvantages
Low cost	Does not control mosquitos
Can be built by householder	Extra cost of providing vent pipe
Needs no water for operation	Need to keep interior dark
Easily understood	
Control of flies	
Absence of smell in latrines	

Pour-flush latrine

A latrine may be fitted with a trap providing a water seal, which is cleared of faeces by pouring in sufficient quantities of water to wash the solids into the pit and replenish the water seal. A water seal prevents flies, mosquitos and odours reaching the latrine from the pit. The pit may be offset from the latrine by providing a short length of pipe or covered channel from the pan to the pit. The pan of an offset pour flush latrine is supported by the ground and the latrine may be within or attached to a house.

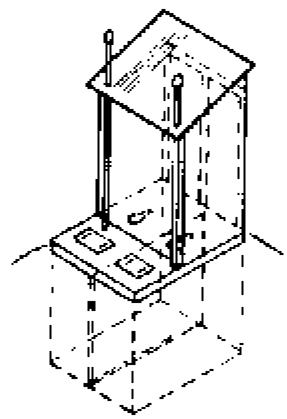


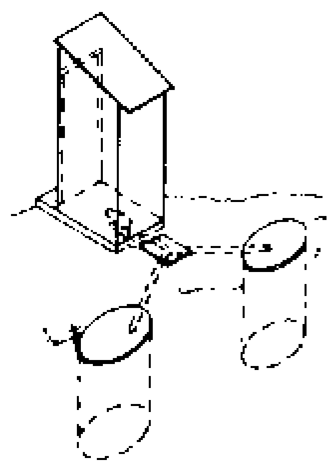
Advantages	**Disadvantages**
Low cost	A reliable (even if limited) water supply must be available
Control of flies and mosquitos	Unsuitable where solid anal cleaning material is used
Absence of smell m latrine	Contents of pit not visible
Offset type	Gives users the convenience of a WC
Pan supported by ground	Can be upgraded by connection to sewer when sewerage becomes available
Latrine can be in house	

Single or double pit

In rural and low-density urban areas, the usual practice is to dig a second pit when the one in use is full to within half a metre of the slab. If the superstructure and slab are light and prefabricated they can be moved to a new pit. Otherwise a new superstructure and slab have to be constructed. The first pit is then filled up with soil. After two years, faeces in the first pit will have completely decomposed and even the most persistent pathogens will have been destroyed. When another pit is required the contents of the first pit can be dug out (it is easier to dig than undisturbed soil) and the pit can be used again. The contents of the pit may be used as a soil conditioner.

Alternatively, two lined pits may be constructed, each large enough to take an accumulation of faecal solids over a period of two years or more. One pit is used until it is full, and then the second pit is used until that too is full, by which time the contents of the first pit can be removed and used as a fertilizer with no danger to health. The first pit can then be used again.

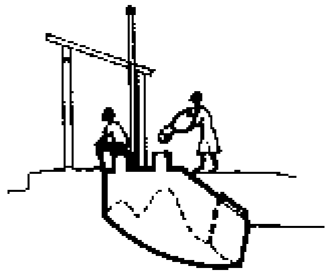




Advantages of single pits	Advantages of double pits
Will last for several years if large enough	Once constructed the pits are more or less permanent
	Easy removal of solids from the pits as they are shallow
	Pit contents can be safely used as a soil conditioner alter 2 years, without treatment

Composting latrine

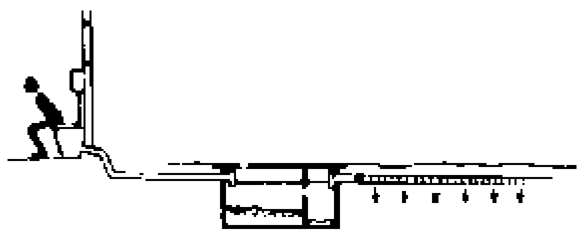
In this latrine, excrete fall into a watertight tank to which ash or vegetable matter is added. If the moisture content and chemical balance are controlled, the mixture will decompose to form a good soil conditioner in about four months. Pathogens are killed in the dry alkaline compost, which can be removed for application to the land as a fertilizer. There are two types of composting latrine: in one, compost is produced continuously, and in the other, two containers are used to produce it in batches.



Advantages	Disadvantages
A valuable humus is produced	Careful operation is essential
	Urine has to be collected separately in the batch system
	Ash or vegetable matter must be added regularly

Septic tank

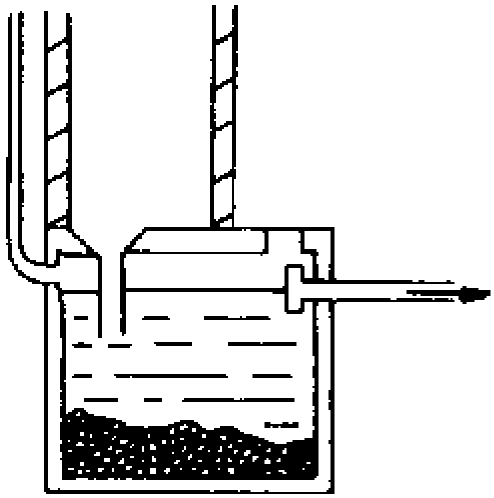
A septic tank is an underground watertight settling chamber into which raw sewage is delivered through a pipe from plumbing fixtures inside a house or other building. The sewage is partially treated in the tank by separation of solids to form sludge and scum. Effluent from the tank infiltrates into the ground through drains or a soakpit. The system works well where the soil is permeable and not liable to flooding or waterlogging, provided the sludge is removed at appropriate intervals to ensure that it does not occupy too great a proportion of the tank capacity.



Advantages	Disadvantages
Gives the users the convenience of a WC	High cost
	Reliable and ample piped water required
	Only suitable for low-density housing
	Regular dislodging required and sludge needs careful handling
	Permeable soil required

Aqua-privy

An aqua-privy has a watertight tank immediately under the latrine floor. Excreta drop directly into the tank through a pipe. The bottom of the pipe is submerged in the liquid in the tank, forming a water seal to prevent escape of flies, mosquitos and smell. The tank functions like a septic tank. Effluent usually infiltrates into the ground through a soakpit. Accumulated solids (sludge) must be removed regularly. Enough water must be added to compensate for evaporation and leakage losses.

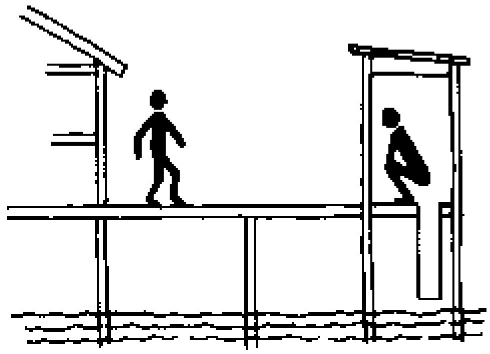


Advantages	**Disadvantages**
Does not need piped water on site	Water must be available nearby
Less expensive than a septic tank	More expensive than VIP or pour-flush latrine
	Fly mosquito and smell nuisance if seal is lost because insufficient water is added
	Regular desludging required and sludge needs careful handling
	Permeable soil required to dispose of effluent

Removal systems for excrete

Overhung latrine

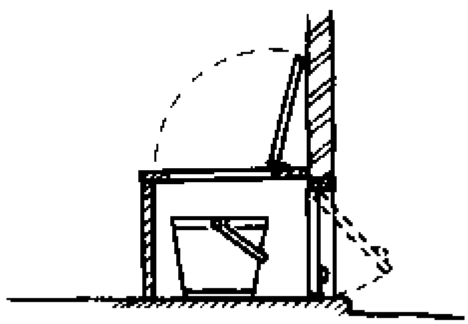
A latrine built over the sea, a river, or other body of water into which excrete drop directly, is known as an overhung latrine. If there is a strong current in the water the excrete are carried away. Local communities should be warned of the danger to health resulting from contact with or use of water into which excrete have been discharged.



Advantages	Disadvantages
May be the only feasible system for communities living over water	Serious health risks
Cheap	

Bucket latrine

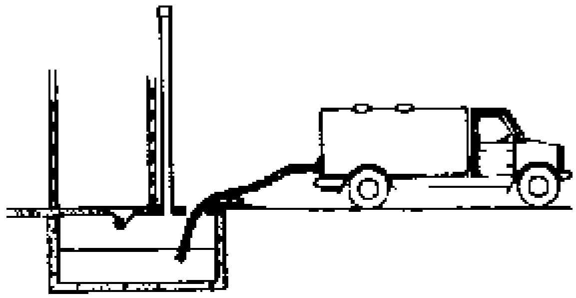
This latrine has a bucket or other container for the retention of faeces (and sometimes urine and anal cleaning material), which is periodically removed for treatment or disposal. Excreta removed in this way are sometimes termed nightsoil.



Advantages	Disadvantages
Low initial cost	Malodorous
	Creates fly nuisance
	Danger to health of those who collect or use the nightsoil
	Collection is environmentally and physically undesirable

Vaults and cesspits

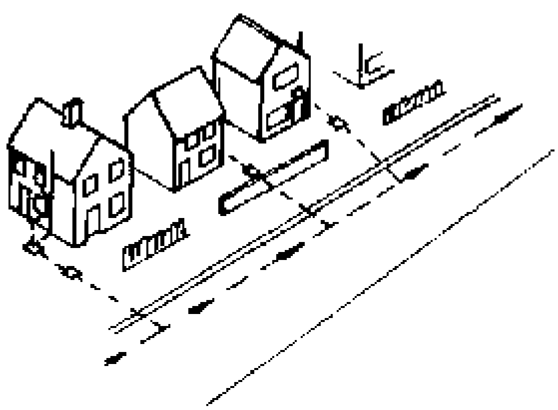
In some areas, watertight tanks called vaults are built under or close to latrines to store excrete untie they are removed by hand (using buckets or similar receptacles) or by vacuum tanker. Similarly, household sewage may be stored in larger tanks called cesspits, which are usually emptied by vacuum tankers. Vaults or cesspits may be emptied when they are nearly full or on a regular basis.



Advantages	Disadvantages
Satisfactory for users where there is a reliable and safe collection service	High construction and collection costs
	Removal by hand has even greater health risks than bucket latrines
	Irregular collection can lead to tanks overflowing
	Efficient infrastructure required

Sewerage

Discharge from WCs and other liquid wastes flow along a system of sewers to treatment works or directly into the sea or a river.



Advantages	Disadvantages
User has no concern with what happens after the WC is flushed	High construction costs
No nuisance near the household	Efficient infrastructure required for construction, operation and maintenance
Treated effluent can be used for irrigation	Ample and reliable piped water supply required (a minimum of 70 litres per person per day is recommended)
	If discharge is to a water-course, adequate treatment required to avoid pollution

Sewers of smaller diameter than usual (small-bore sewerage), sewers built nearer to the surface than usual, and sewers with flatter gradient than usual have been tried. Many of these systems require a chamber at each house to retain solids, which have to be removed and disposed of from time to time. Some of these systems have been found to be suitable for providing sanitation simultaneously for a large number of high-density dwellings.

Part II - Detailed design, construction, operation and maintenance

Chapter 5 - Technical factors affecting excrete disposal

Human wastes

Volume of fresh human wastes

The amount of faeces and urine excreted daily by individuals varies considerably depending on water consumption, climate, diet and occupation. The only way to obtain an accurate determination of the amount at a particular location is direct measurement. Table 5.1 shows some reported average quantities of faeces excreted by adults (grams per person per day).

Even in comparatively homogeneous groups there may be a wide variation in the amounts of excrete produced. For example, Egbunwe (1980) reported a range of 500-900 g of faeces per person per day in eastern Nigeria. Generally, active adults eating a high-fibre diet and living in a rural area produce more faeces than children or elderly people living in urban areas eating a low-fibre diet. Both Shaw (1962) and Pradt (1971) suggested that the total amount of excrete is about one litre per person per day.

The amount of urine is greatly dependent on temperature and humidity, commonly ranging from 0.6 to 1.1 litres per person per day.

In the absence of local information the following figures are suggested as reasonable averages:

- high-protein diet in a temperate climate: faeces 120 g, urine 1.21, per person per day.
- vegetarian diet in a tropical climate: faeces 400 g, urine 1.01, per person per day.

Table 5.1. Quantity of wet faeces excreted by adults (in grams per person per day)

Place	Quantity	Reference
China (men)	209	Scott (1952)
India	255	Macdonald (1952)
India	311	Tandon & Tandon (1975)
Peru (rural Indians)	325	Crofts (1975)
Uganda (villagers)	470	Burkitt et al. (1974)
Malaysia (rural)	477	Balasegaram & Burkitt (1976)
Kenya	520	Cranston & Burkitt (1975)

Decomposition of faeces and urine

As soon as excrete are deposited they start to decompose, eventually becoming a stable material with no unpleasant smell and containing valuable plant nutrients. During decomposition the following processes take place.

- Complex organic compounds, such as proteins and urea, are broken down into simpler and more stable forms.

- Gases such as ammonia, methane, carbon dioxide and nitrogen are produced and released into the atmosphere.

- Soluble material is produced which may leach into the underlying or surrounding soil or be washed away by flushing water or groundwater.

- Pathogens are destroyed because they are unable to survive in the environment of the decomposing material.

The decomposition is mainly carried out by bacteria although fungi and other organisms may assist. The bacterial activity may be either aerobic, i.e., taking place in the presence of air or free oxygen (for example, following defecation and urination on to the ground), or anaerobic, i.e., in an environment containing no air or free oxygen (for example, in a septic tank or at the bottom of a pit). In some situations both aerobic and anaerobic conditions may apply in turn. When all available oxygen has been used by aerobic bacteria, facultative bacteria capable of either aerobic or anaerobic activity take over, and finally anaerobic organisms commence activity.

Pathogens may be destroyed because the temperature and moisture content of the decomposing material create hostile conditions. For example, during composting of a mixture of faeces and vegetable waste under fully aerobic conditions, the temperature may rise to 70°C, which is too hot for the survival of intestinal organisms. Pathogens may also be attacked by predatory bacteria and protozoa, or may lose a contest for limited nutrients.

Volumes of decomposed human wastes

As excrete become decomposed they are reduced in volume and mass owing to:

- evaporation of moisture;

- production of gases which usually escape to the atmosphere;

- leaching of soluble substances;

- transport of insoluble material by the surrounding liquids;

- consolidation at the bottom of pits and tanks under the weight of superimposed solids and liquids.

Little information is available regarding the rate at which the reduction takes place although there are indications that temperature is an important factor (Mare & Sinnatamby, 1986). Weibel et al. (1949) measured the sludge accumulation rate in 205 septic tanks in the United States of America, and obtained the results shown in Fig. 5. 1; other authors have reported the accumulation rates listed in Table 5.2.

Fig. 5.1. Rate of accumulation of' sludge and scum In 205 septic tanks in the United States of America (from Weibel et al., 1949)

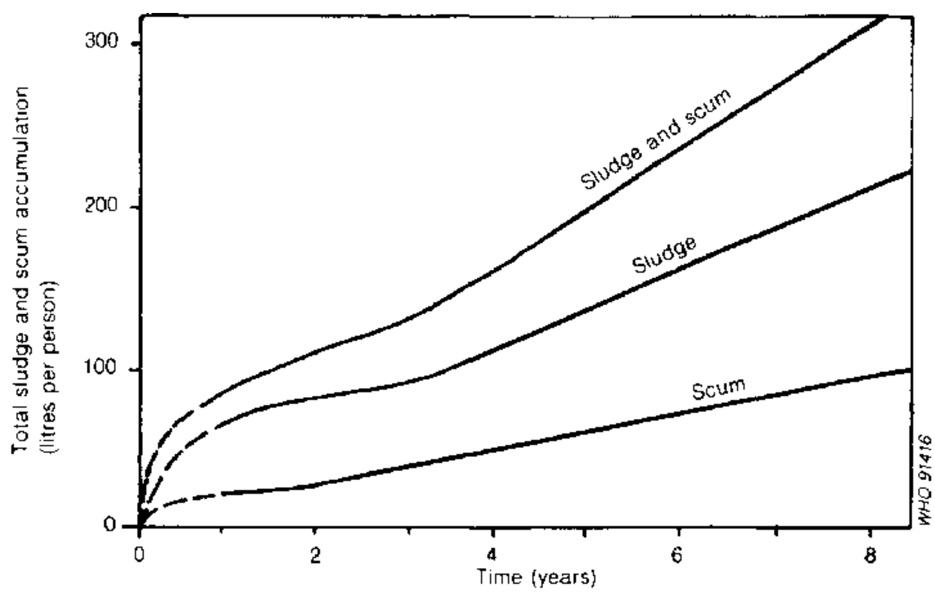


Table 5.2. Excreta accumulation rates (litres per person per year)

Location	Accumulated excreta	Remarks	Reference
Zimbabwe	20	Latrine regularly washed down; degradable cleaning material	Morgan & Mara (1982)
West Bengal	25	Wet pit---ablution water used	Wagner & Lanoix (1958)
West Bengal	34	Wet pit	Baskaran (1962)
Philippines	40	Wet pit; degradable cleaning material	Wagner & Lanoix (1958)
USA	42	Faeces (adult); half amount for children	Geyer et al. (1968)
Brazil	47	Dry pit	Sanches & Wagner (1954)
Philippines	60	Dry pit; degradable cleaning material	Wagner & Lanoix (1958)

The factors with the biggest effect on the sludge accumulation rate are whether decomposition takes place above or below the water table and the type of anal cleaning material used. Decomposition under water produces a much greater reduction in volume than decomposition in air. This is due to better consolidation, more rapid decomposition and removal of the finer material in the water flow. Anal cleaning materials vary widely around the world, from those requiring little or no storage space, such as water, to those having a greater volume than the excrete, such as corn cobs, cement bags or stones.

Table 5.3. Suggested maximum sludge accumulation rates (litres per person per year)

	Sludge accumulation rate
Wastes retained in water where degradable anal cleaning materials are used	40
Wastes retained in water where non-degradable anal cleaning materials are used	60
Waste retained in dry conditions where degradable anal cleaning materials are used	60
Wastes retained in dry conditions where non degradable anal cleaning materials are used	90

When designing a latrine it is strongly recommended that local sludge accumulation rates should be measured. In the absence of local data, the volumes given in Table 5.3 are suggested as a maximum. There is some evidence to indicate that these figures are on the high side. However, if refuse is added to excrete, the accumulation rate may be much greater.

Where excrete are stored for short periods only, such as in double pit latrines or composting toilets, the reduction process may not be complete before the sludge is removed. In such cases it will be necessary to use higher sludge accumulation rates than indicated above. A 50% increase is tentatively suggested.

Ground conditions

Ground conditions affect the selection and design of sanitation systems, and the following five factors should be taken into consideration:

- bearing capacity of the soil;
- self-supporting properties of the pits against collapse;
- depth of excavation possible;
- infiltration rate;
- groundwater pollution risk.

Bearing capacity of the soil

All structures require foundations, and some soils are suitable only for lightweight materials because of their poor load-carrying capacity - marshy and peaty soils are obvious examples. In general, it is safe to assume that if the ground is suitable for building a house it will be strong enough to support the weight of a latrine superstructure made of similar materials, providing the pit is appropriately lined.

Self-supporting properties of the pits

Many types of latrine require the excavation of a pit. Unless there is specific evidence to the contrary (i.e., an existing unlined shallow well that has not collapsed), it is recommended that all pits should be lined to their full depth. Many soils may appear to be self-supporting when first excavated, particularly cohesive soils, such as clays and silts, and naturally bonded soils, such as laterites and soft rock. These self supporting properties may well be lost over time owing to changes in the moisture content or decomposition of the bonding agent through contact with air and/or moisture. It is almost impossible to predict when these changes are likely to occur or even if they will occur at all. It is therefore safer to line the pit. The lining should permit liquid to percolate into the surrounding soil.

Depth of excavation

Loose ground, hard rock or groundwater near to the surface limit the depth of excavation possible using simple hand tools. Large rocks may be broken if a fire is lit around them and then cold water poured on the hot rock. Excavation below the water table and in loose ground is possible by "caissoning" (see Chapter 7), but it is expensive and not usually suitable for use by householders building their own latrines.

Infiltration rate

The soil type affects the rate at which liquid infiltrates from pits and drainage trenches. Clays that expand when wet may become impermeable. Other soils such as silts and fine sands may be permeable to clean water but become blocked when transmitting effluent containing suspended and dissolved solids.

Opinions vary regarding the areas through which infiltration takes place. For example, Lewis et al. (1980) recommended that only the base of pits or drainage trenches should be considered and that lateral movement (the sidewall influence) be ignored. Mara